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On Prerequisites to Large Scale Rollout of CSP in Southern Africa: *Models, Plants and Resources*

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Dept. Mechanical & Mechatronic Research Lecture
22 November 2010

Fakulteit Ingenieurswese
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Faculty of Engineering

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Agenda

- Background
- Research objective
  - Modelling
  - Plants
  - Resources
  - Risks
- Conclusions

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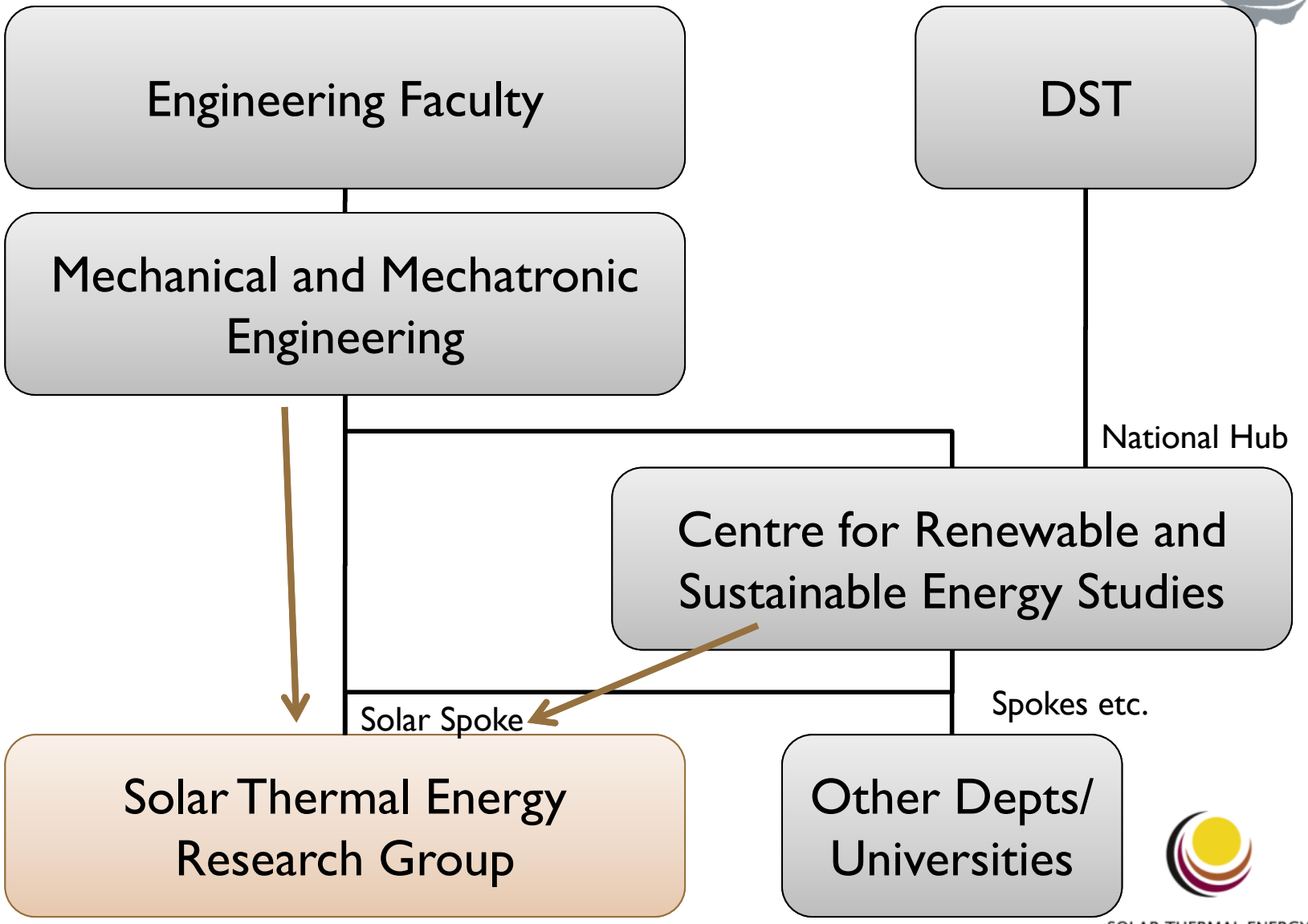
Where STERG Fits



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Solar Thermal History at SU

1980 - 1989	1990 - 1999	2000 – 2009	2010 -

~1970

First Parabolic Trough Research

Dry Cooling Research Commences

Solar Chimney Research Commences

RENEWABLE & SUSTAINABLE ENERGY STUDIES

National RE Centre Founded

Solar Roof Lab Commissioned

SASTELA

Research and Academic Committee Representative

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Solar Resource Station at SU

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STERG Research Structure

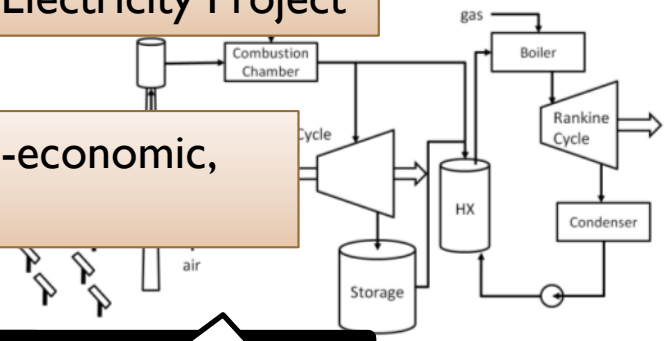
STERG Holistic/Multidisciplinary Research

Social & Political Sciences | Engineering | Economic Sciences

SWH, Process Heat, Desalination etc.

SUNSTEL
Stellenbosch University Solar Thermal Electricity Project

System R&D (Modelling, Techno-economic, Resources, etc)



Solar Resource Measure & R&D

Component R&D: Eg. Dry Cooling

Component R&D: Eg. Thermal Storage

Component R&D: Eg. Heliostats

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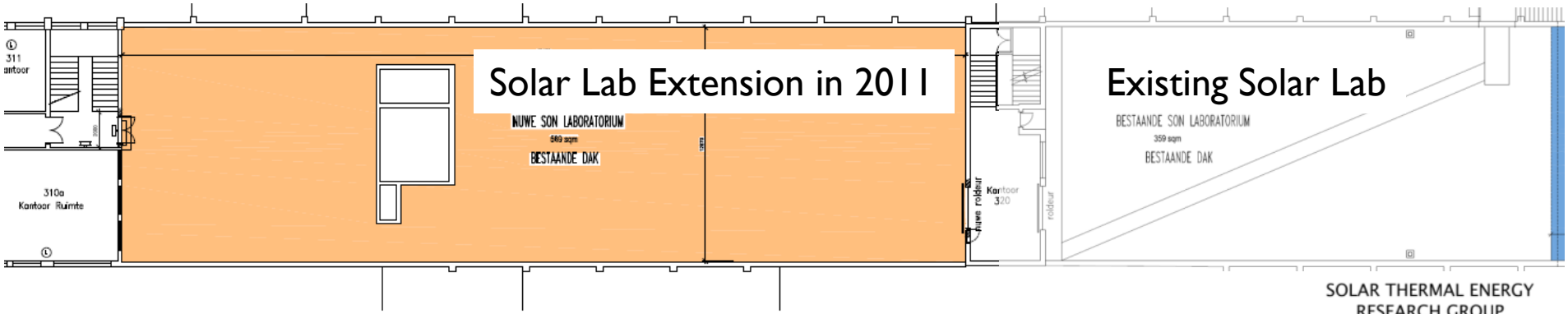
STERG Infrastructure

- Primary sponsors: OSP/Hope Project, Sasol, DST
- Full time solar thermal energy researcher, engineer, technician (½)
- 15+ Staff and post-graduate students
- Extended solar roof lab (954m^2)
- Solar & weather resource measurement station
- Multiple heat transfer and wind-tunnel labs.



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Research Objective

- **Title**: ***Techno-Economic Prerequisites to Large Scale Rollout of Concentrating Solar Power in Southern Africa***
  - **Promoters**: Prof. T.W von Backström & Prof A.C. Brent (School of Public Leadership)
  - **Advisory**: Prof. D.G. Kröger, Prof. J.L. van Niekerk, [Dr.] H.C.R. Reuter
- **Objective:** Holistic project for SA to be "technology ready". Covers:
  - Ability to **model** plants (from decision making to dispatch)
  - Understand technology asymptotes and 2050
  - Address the *"we don't know what we don't know"* through encouraging/building any and all research/pilot/demo **plants**
  - Build scenarios of the large scale rollout considering **resources**

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Research Objective

- **Reason**: Early-stage for CSP in Southern Africa → Need macro level technology expertise for urgently needed planning at IRP (Integrated Resource Planning) level
- **Strategic & Appropriate**: CSP could be to 21st century South Africa what the Fischer–Tropsch process was to 20th century South Africa
- **Other**:
  - Fits well with STERG coordination
  - Past multidisciplinary experience
  - Aligns with sponsor goals

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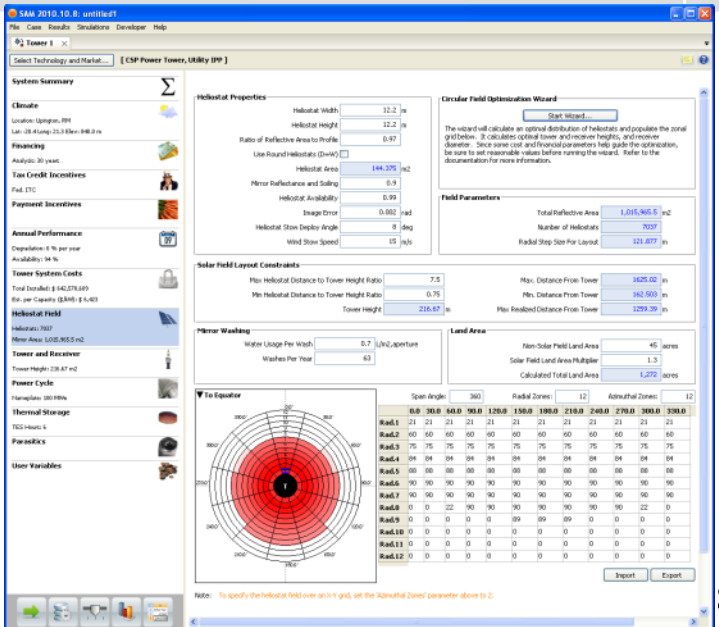
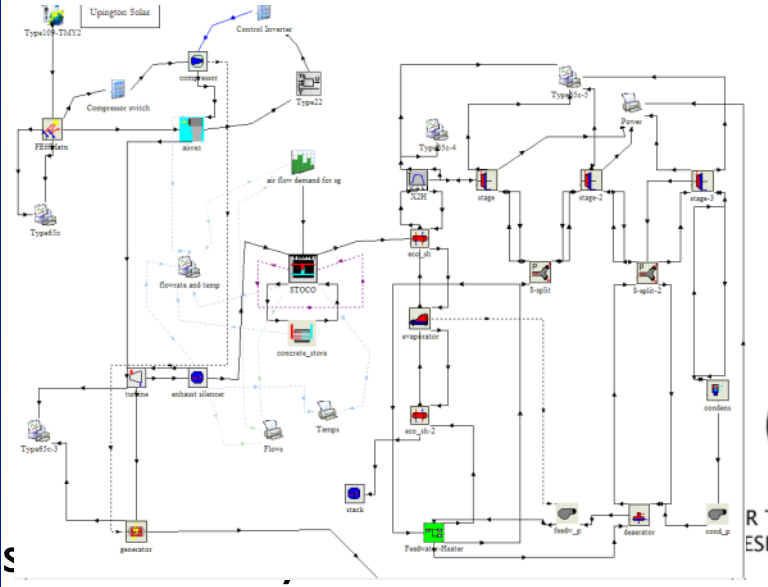
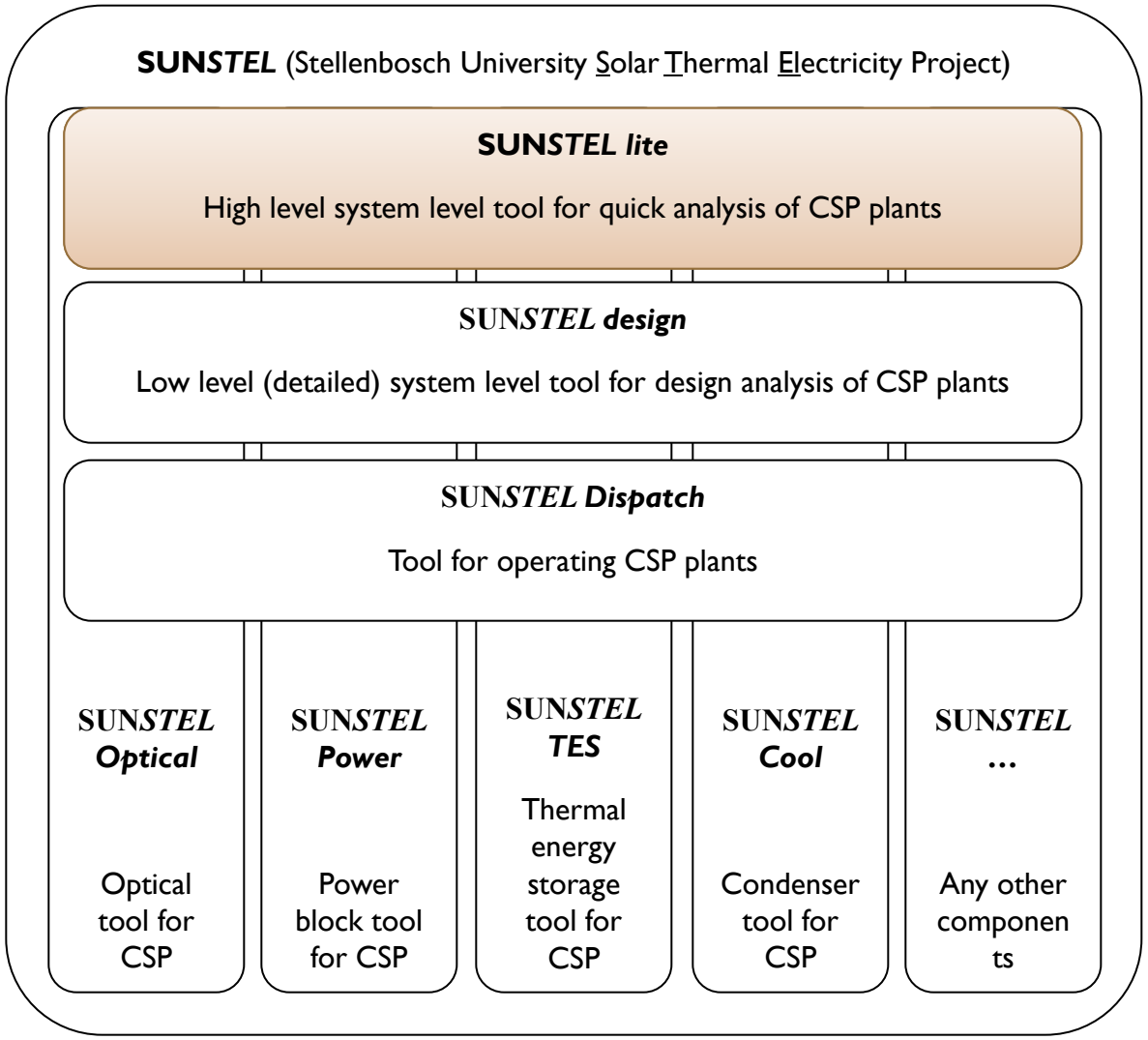
System Modelling for CSP Plants

Tool	Pros	Cons
System Advisor Model (SAM) by National Renewable Energy Lab (NREL)	•Quite easy •Good solver (TRNSYS) •Is validated	•Highly restrictive to built in configs
TRNSYS by University Wisconsin	•Good solver •Flexible use	•Very difficult to use for the untrained user
DLR consortium	•Hope for a standard	•Proprietary and hard to get in?
Flownex	•SA tool and support	•Doesn't do any solar
Build own models and code	•Develop skills	•Will take time





Proposal: Own Code for SUN*STEL*

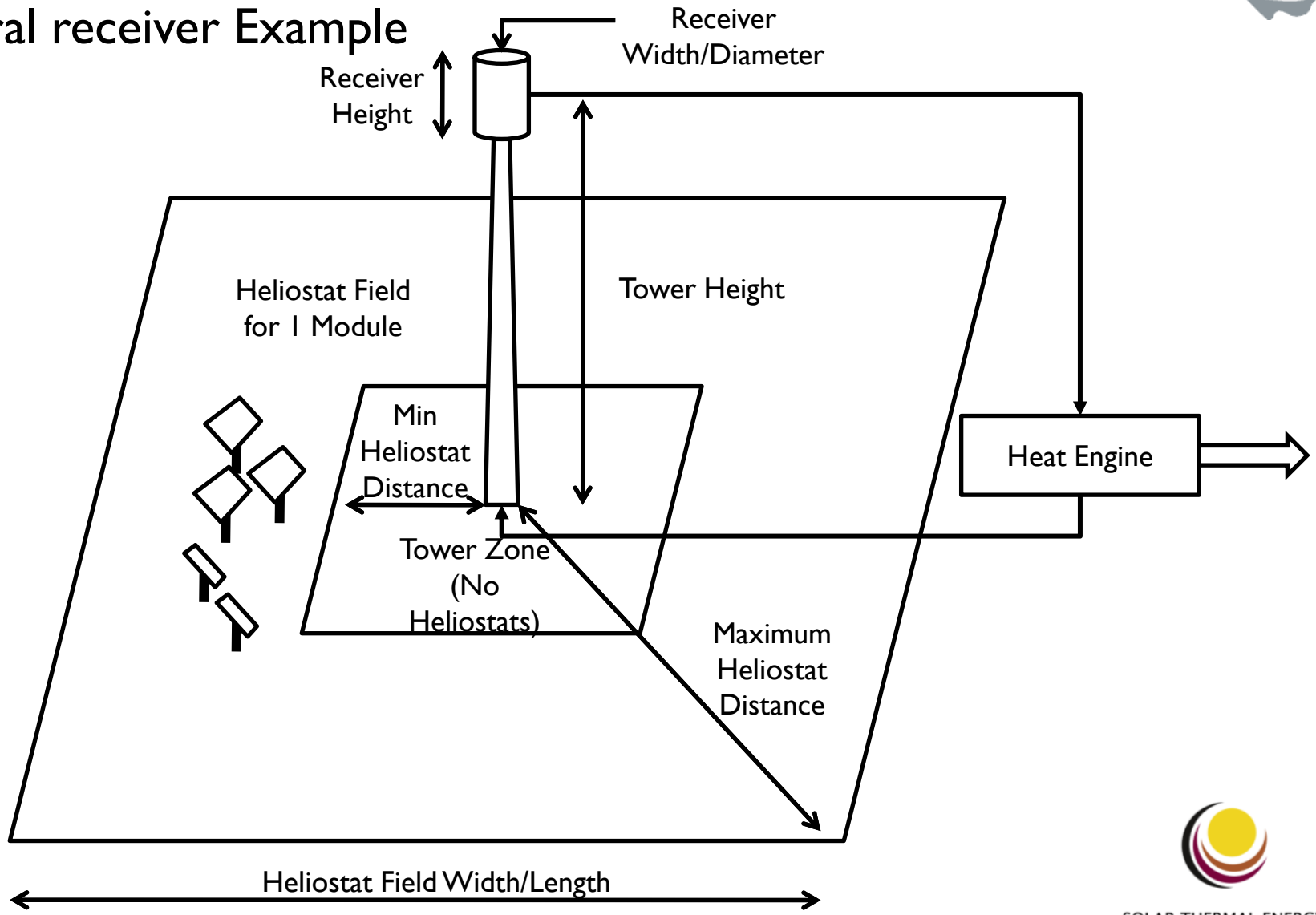


SUN*STEL* Lite

- Approach per objective
  - Only the appropriate level of modelling for needs (Eg. Decision makers)
  - Looks at the big 5
    - Central Receiver
    - Parabolic Trough
    - Linear Fresnel
    - Dish Stirling
    - Solar Chimney (Special case)
  - Applies same rules to all (provide basis for comparison)
  - Uses hourly data for solar and weather (Day, Month, Hour, DNI, Ta, Wet bulb, Wind speed)
  - Quasi-transient analysis for
    - Energy balance
    - Chambadal-Novikov engine (Modified Carnot)
  - No operating fluids

SUN*STEL* Lite: Only Necessary Plant Metrics

Central receiver Example



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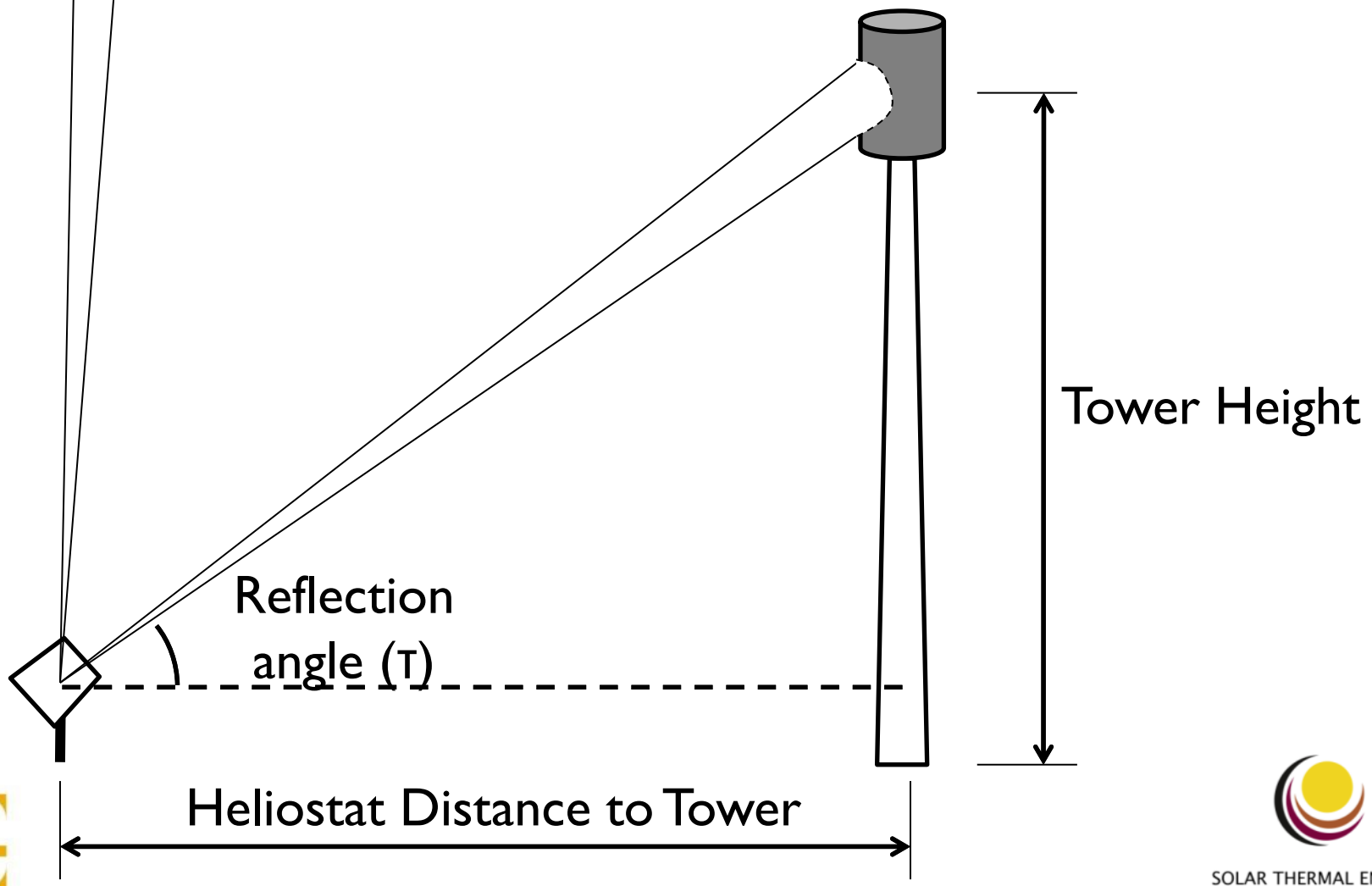
Calculates Solar Physics for Plant Sizing



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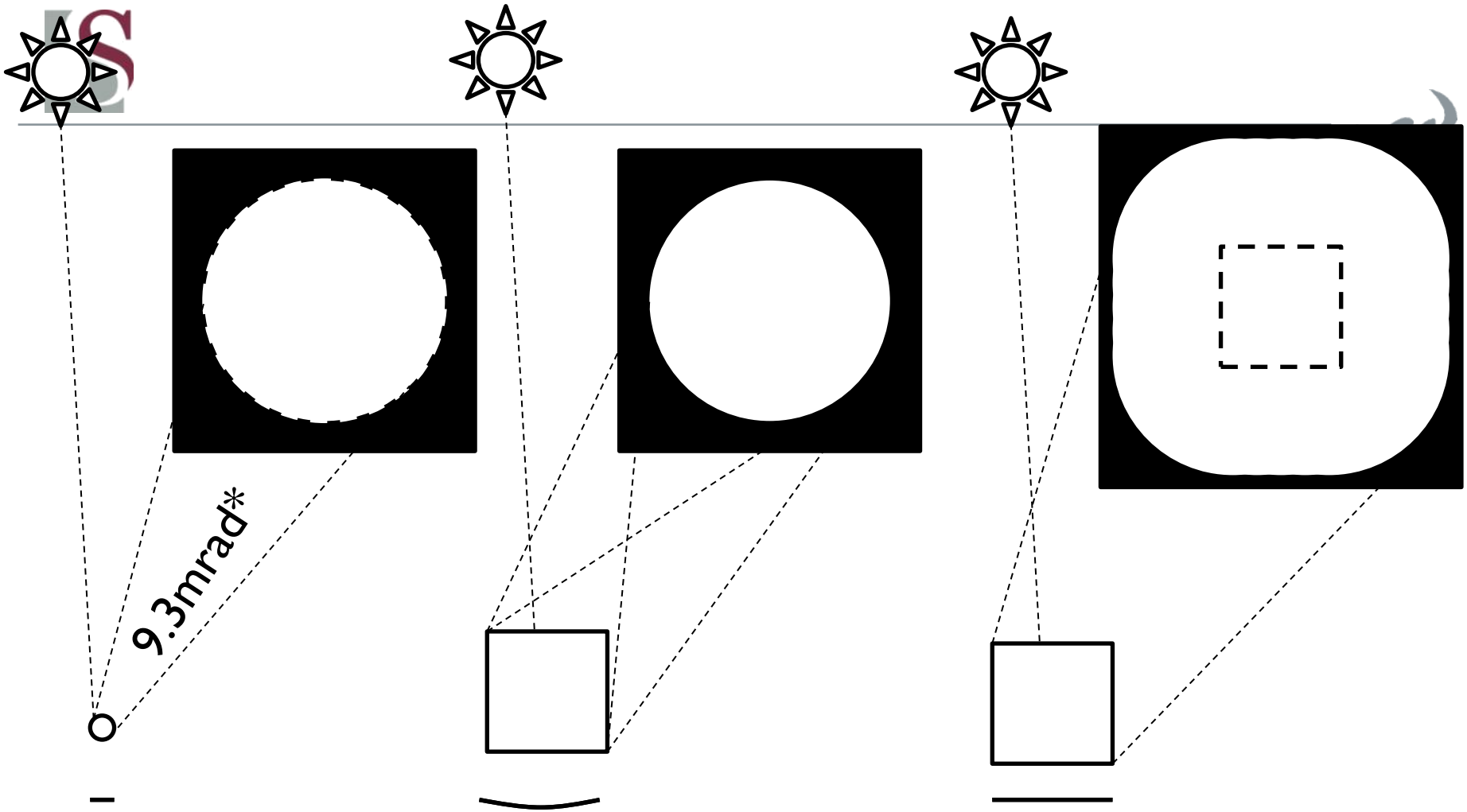

Small Reflector
(~infinitesimal)

Perfectly Curved Square Reflector

Perfectly Flat
Square Reflector

*Subtending angle of the sun. Casts Ø 9.3m image per 1,000m focal distance

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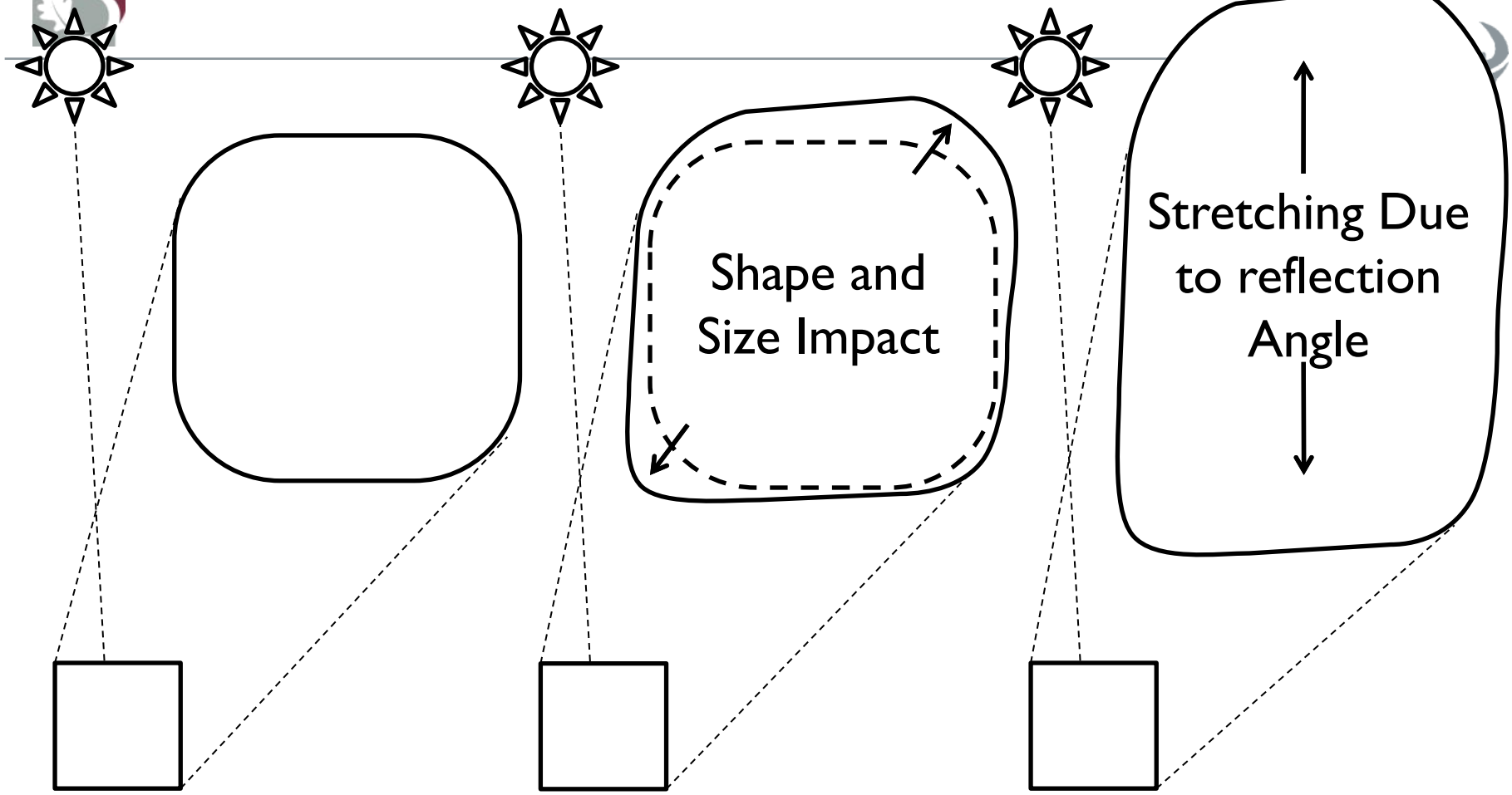

Normal Image Outline
Perfectly Flat Square
Reflector

Normal Image Outline
Real Flat Square
Reflector

Angled Image Outline on
Receiver
Real Flat Square Reflector

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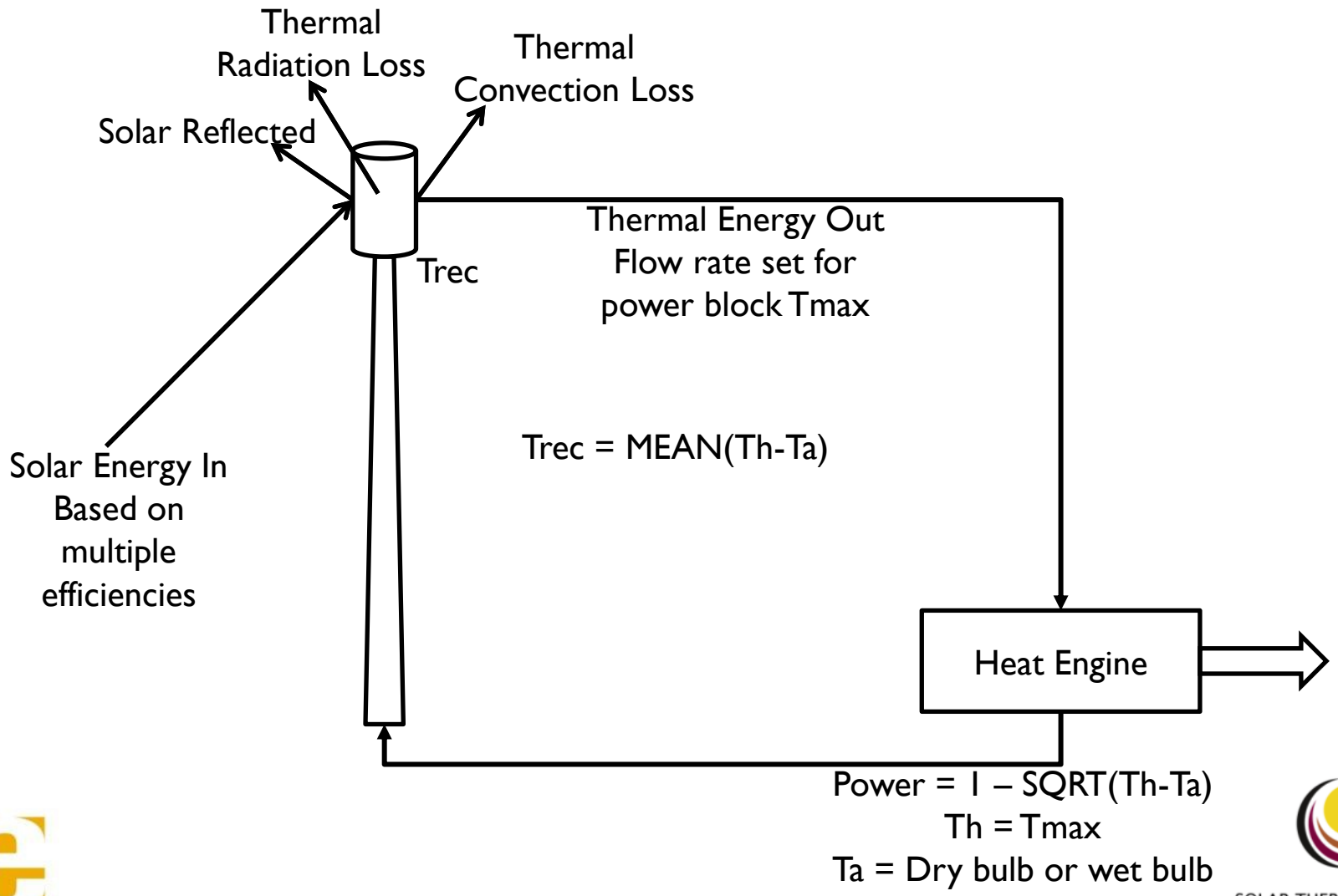
Conceptual Modelling Approach



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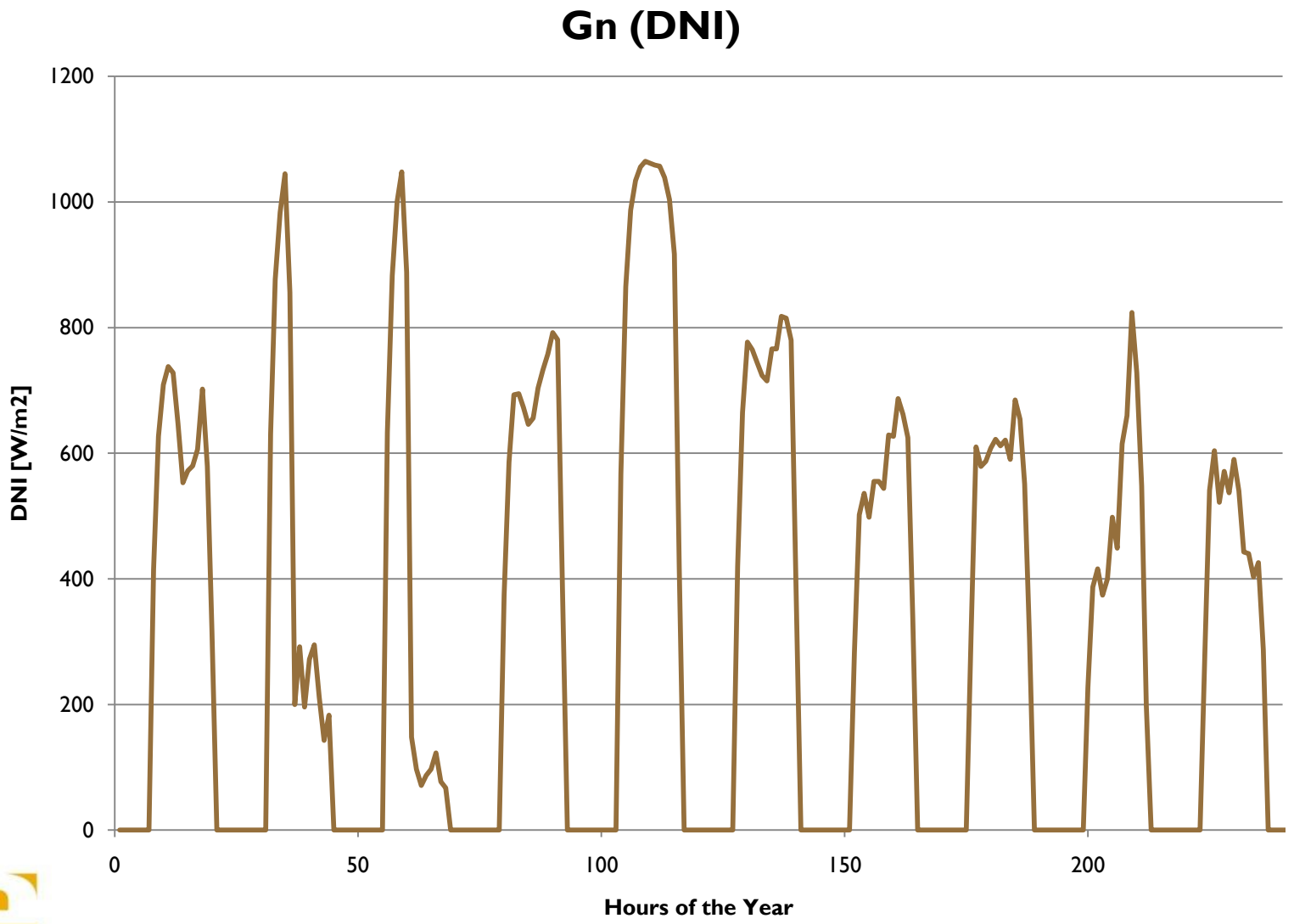
Example of DNI – 10 Days in Upington



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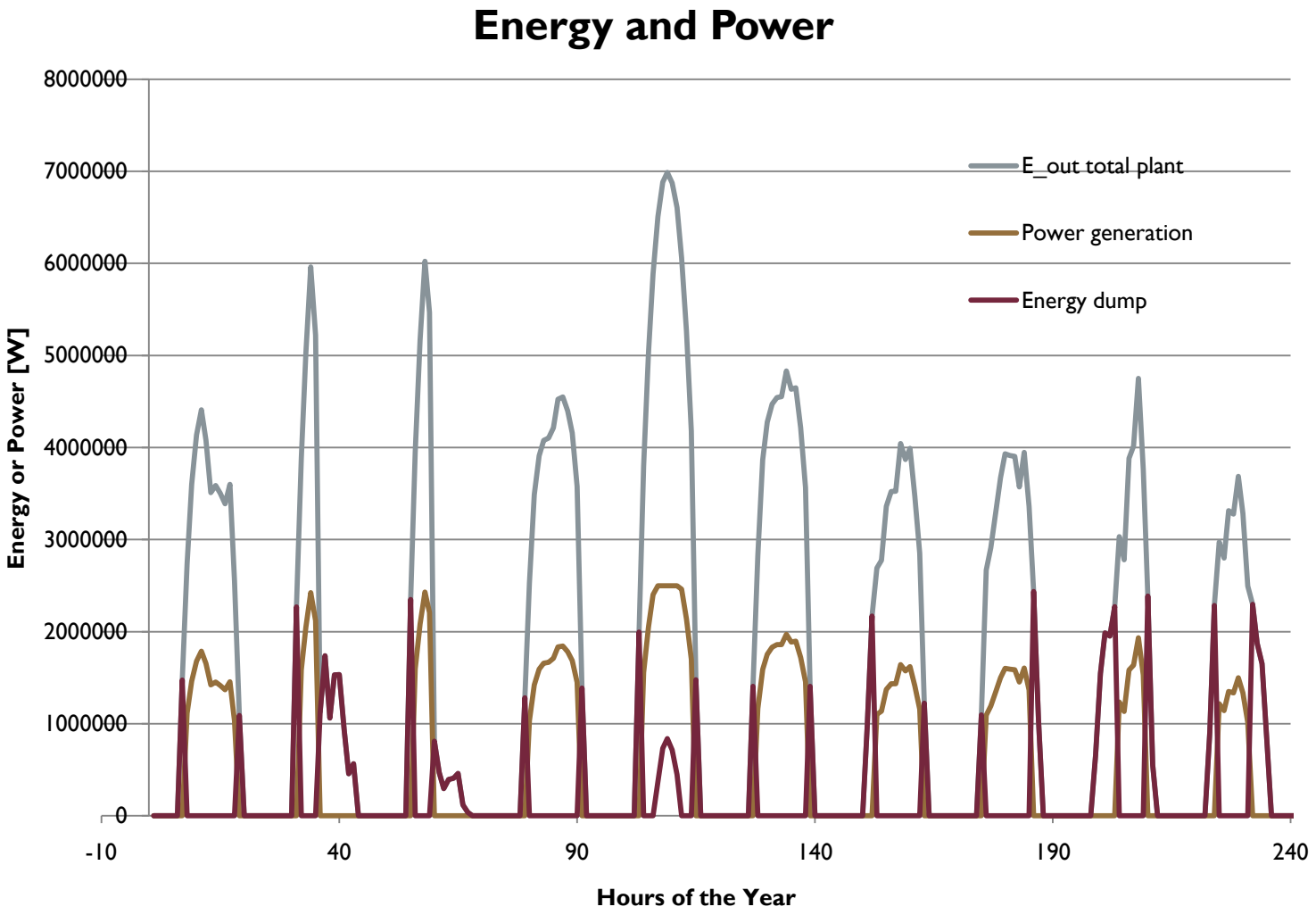
10 Days of Power – 2.5MWe plant



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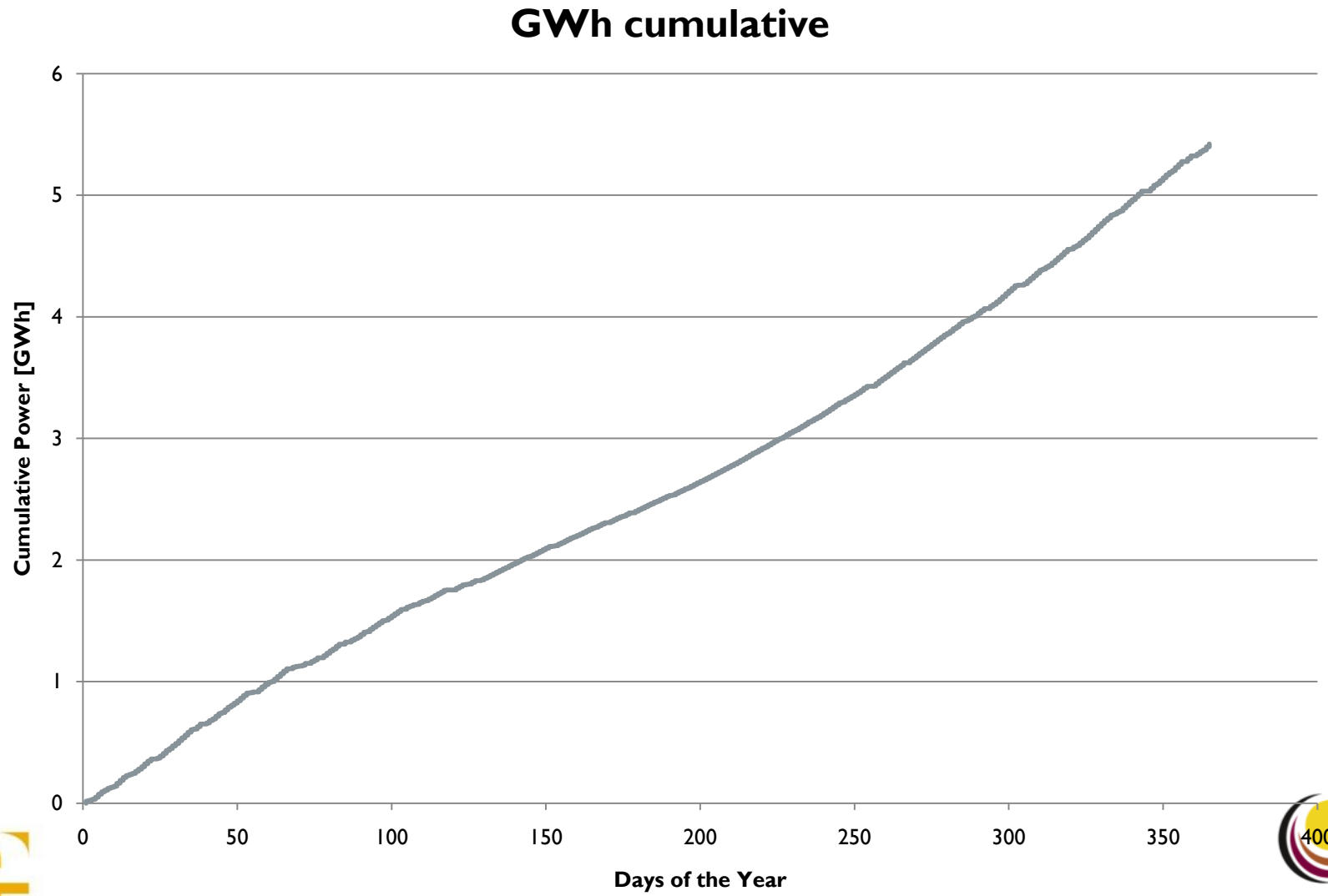
Annual Production – 2.5MWe Upington Plant



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Research – Pilot – Demo Plants

- We don't know what we don't know
- Need to take small steps and grow skills locally
  - Design
  - Build
  - Model
  - Run
  - Debug
  - Improve
  - Build local industry
  - …
- Any and all sizes & types
  - Small (3kWe) troughs and LFRs
  - Pilot sized central receivers at 5MWe
  - Anything in between

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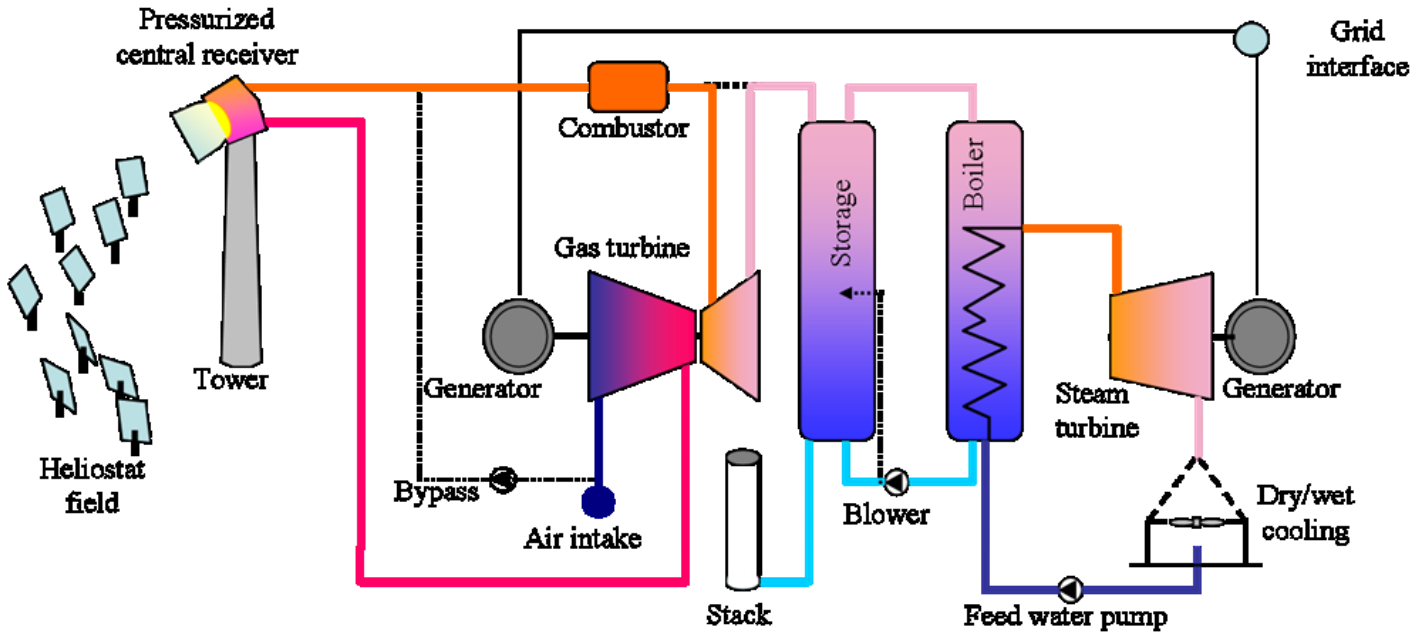
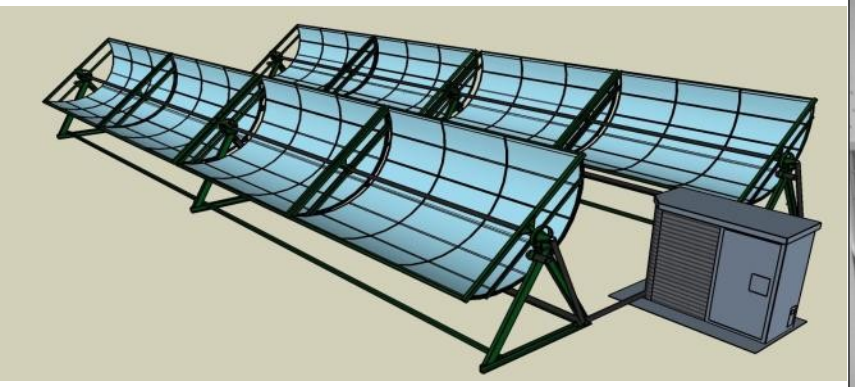
Plants

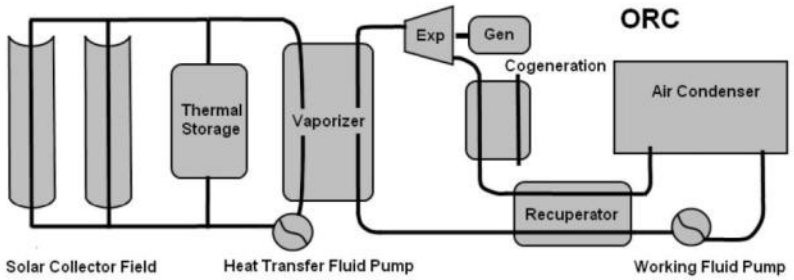
- SUNSPOT high efficiency combined cycle concept – Prof Kröger concept
  - May have an excellent chance to do something like this with an industrial partner

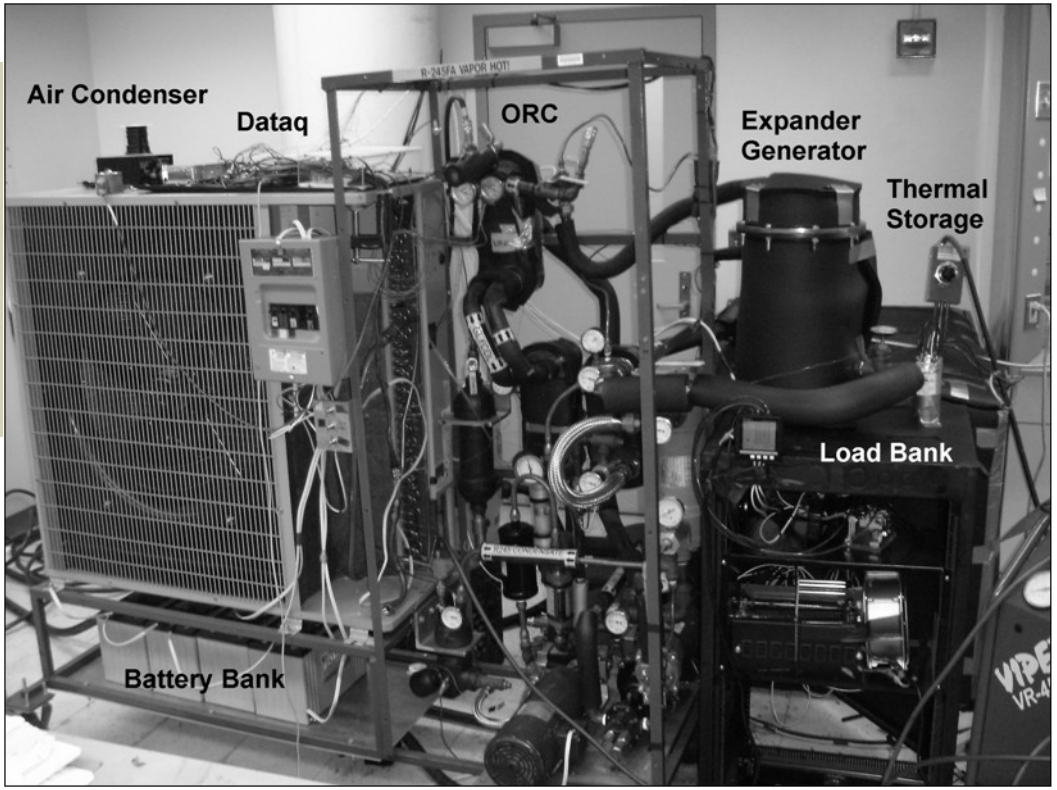


Plants

- Solar Thermal Group (STG) Organic Rankine CSP system for Spier







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Plants

- Other opportunities
  - Technology vendors looking for places to put pilots
  - Spier to go carbon neutral by 2017 → 1-2MWe CSP plant
    - Has many constraints

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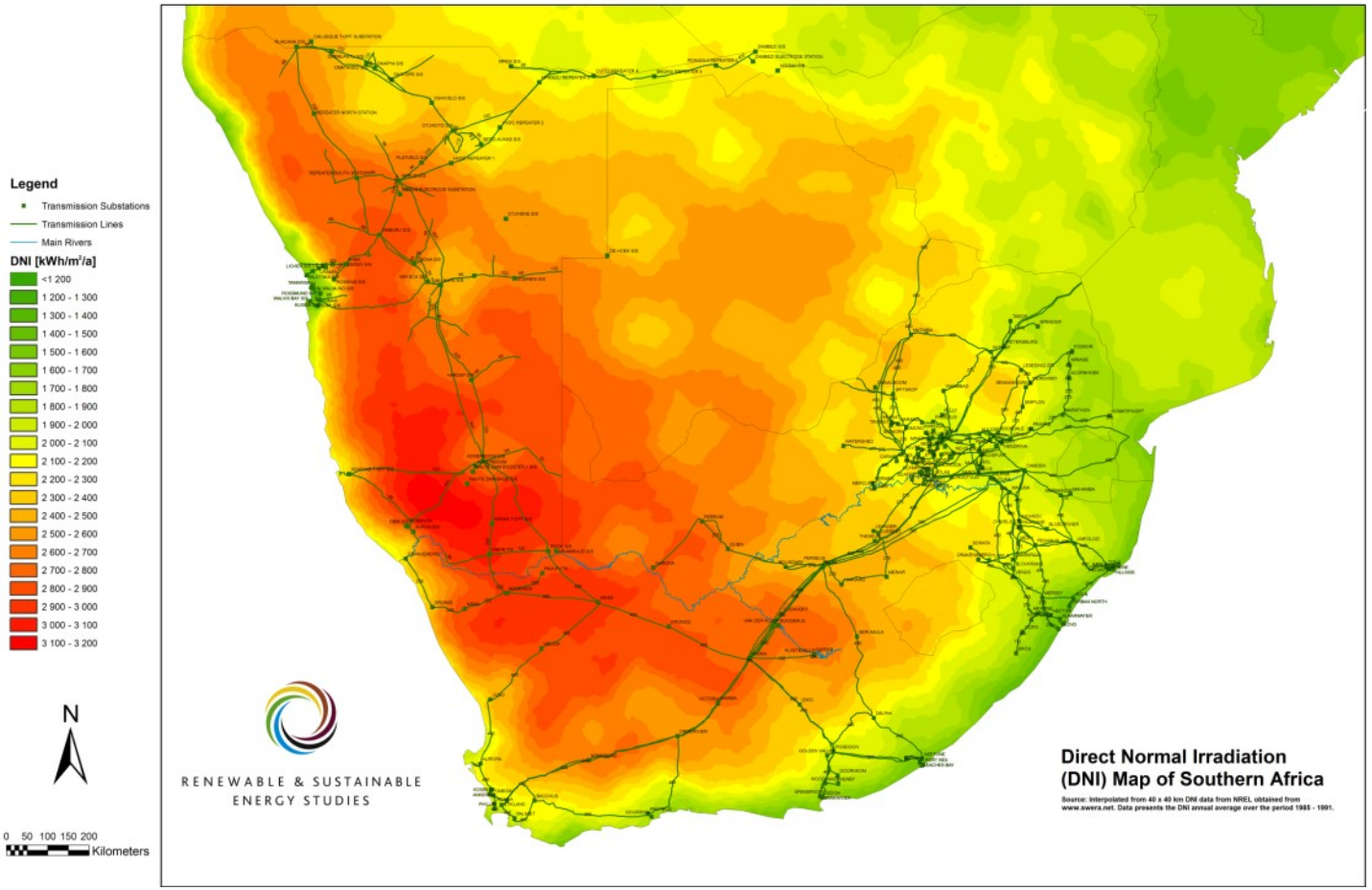
Need to Comprehend the Resource



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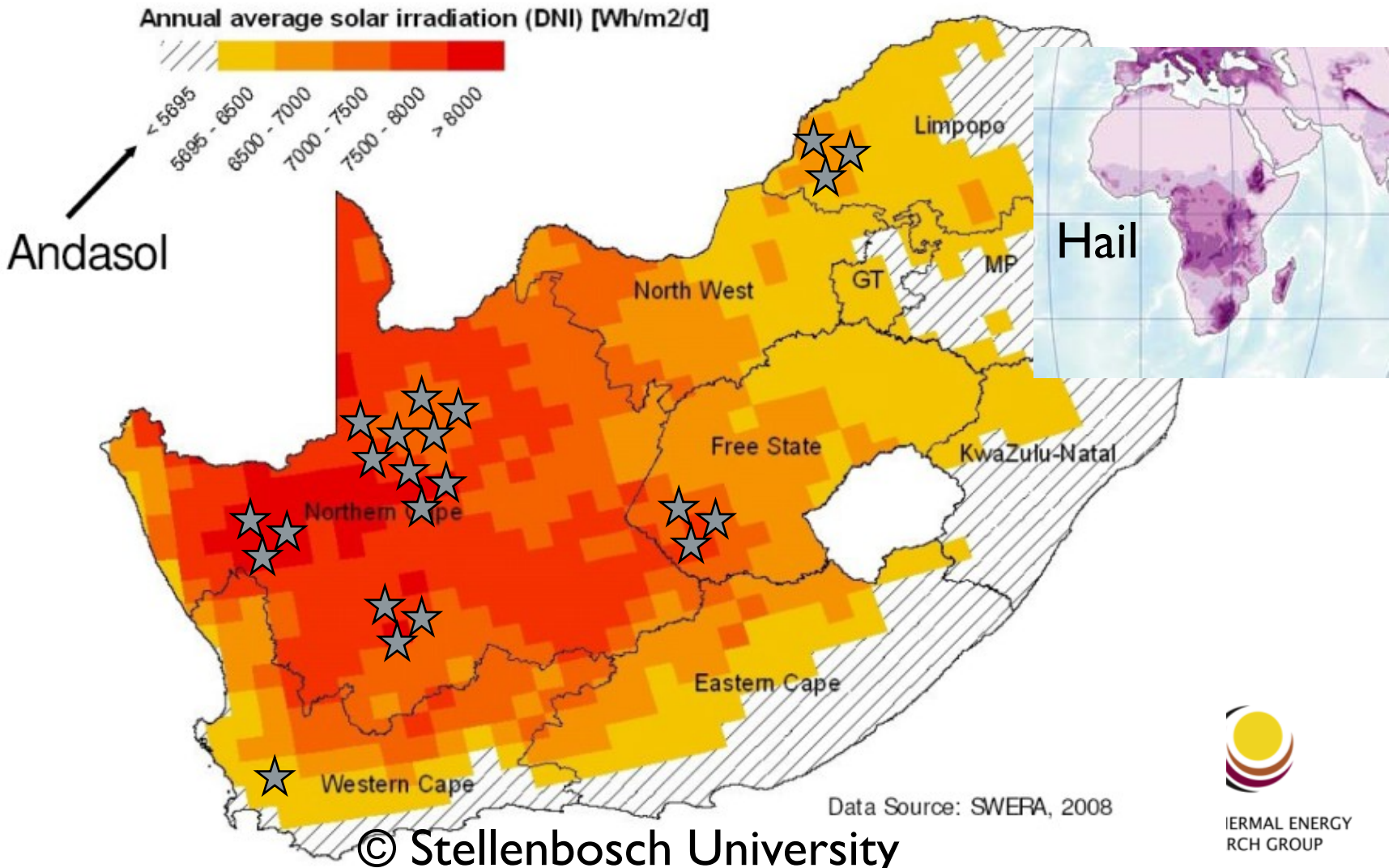
Rollout Model taking Resource Into Account

Mockup on Models of Rollout

★ Locating Plants



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Risks (SWOT)

Strengths	Weakness
✓Multidisciplinary and holistic research ✓Covers system technology and reviews state of art at system level – applicable in SA where the technology and industry is new ✓Close match to job description and sponsor interests ✓Close match with candidate experience	✓Lacks in-depth fundamental research in one particular area ✓Inability to perform laboratory experiments ✓May be wider in scope than any one promoter can comfortably handle
Opportunities	**Risks**
✓Highest level of knowledge transfer to the public (and University) ✓High level of learning about CSP for the candidate – good level of employability ✓May help to broaden solar thermal energy research group into multidisciplinary realm	✓University acceptance of multidisciplinary research topic ✓Harder to constrain the work – volume could spiral – risk of completion ✓Validation and experimentation is either abstract or requires significant financial investment or is of timeframe not in PhD realm

✓: Addressed in planning

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Conclusions

- Looking towards 2050 – For SA to take the opportunity
- Macro level research – has risks
- Work starting with models – showing good promise
- Ability to simulate is important for SA – many topics!
- We believe the small steps approach and getting plants built is critical
- Appropriate technology, skills, locations for the rollout

- Feedback Welcome

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Thank You